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Exercise and Diet Patterns as Factors in Forearm Trabecular and Cortical Bone Development in Pubertal Girls

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INTRODUCTION

- Osteoporosis is a bone disease that occurs when the body loses too much bone, makes too little bone, or both; bones become weak and may break from a fall or, in serious cases, from sneezing or minor bumps.[1]
- Osteoporosis alone causes over 8.9 million fractures every year.[2]
- In 2002, in the US, fractures or breaks caused $16 billion in medical expenses.[3]
- Peak bone mass is the highest bone mass (BMC, g), after growth stops.[4]
- In U.S. white girls, peak bone mass is achieved 7 years after first menstruation, or menarche, gynecological age = 0 [Fig 1, unpublished data].
- Adjustable factors like diet and physical activities circum-menarche influence peak bone mass variance [Fig 1, unpublished data].
- Prior work from our parent study has shown that a bone loading index representing arm exercise for 3 years circum-menarche (3yrBLI) predicts bone mass and 2D areal bone density from arm bone scans by dual energy X-ray absorptiometry (DXA). [5]
- The current study will fill a knowledge gap by evaluating: 1) 3yrBLI as a predictor of 3D bone compression (IBS) and torsion (SSIpol) strength indices, and 2) diet as an additional predictor of 2D DXA bone properties [Fig 1, unpublished data].

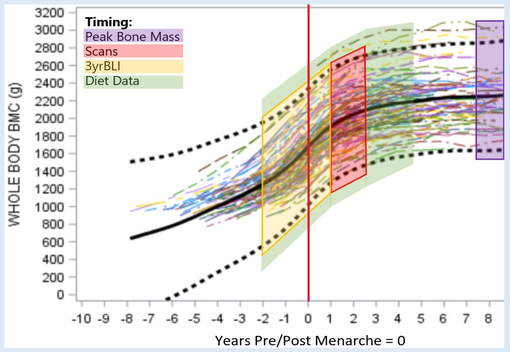


Figure 1: Years Pre/Post Menarche vs. Whole Body BMC (g). Focal data periods and whole body bone mass gains in 123 U.S. girls relative to menarche (Time = 0) [unpublished data].

HYPOTHESES

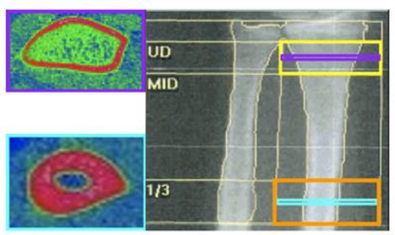
- **H1:** Greater forearm loading (3 year arm BLI) is associated with higher bone compression strength (IBS) [Fig 2]
- **H2:** Greater forearm loading (3 year arm BLI) is associated with higher bone torsional strength (polar SSI) [Fig 3].
- **H3:** Certain diet consumption will predict DXA 2D forearm bone properties positively, including the area, BMC, and BMD at the ⅓ and ultra-distal radius on the non-dominant forearm for girls. Diet variables include protein, total fat, calcium, magnesium, potassium, zinc, and lactose.

METHODS

- Our team developed a circum-menarcheal bone loading index: 3yrBLI=
  Σ [(Magnitude + Velocity) x Frequency x Training Exposure x Non-dominance]

  Magnitude reflects the load put on the forearm, velocity is the amount of impact put on a bone, and the frequency is how many times a load is put on a bone.[5]
- 48 participants were selected from the BLI study who had diet data and acceptable 3D peripheral quantitative computed tomography (pQCT) scans that match up with 3yrArmBLI and DXA scan timing [Fig 1, Fig 2].

Figure 2: The 3D pQCT scan images are shown on the left, and the 2D DXA scan image is shown on the right. The ultradistal region is yellow and the ⅓ region is orange. The 4% pQCT slice is purple and the 33% pQCT slice is turquoise.



Greater arm bone loading exercise predicts greater bone strength indices. Accounting for arm loading, calcium, fat, & protein intake predict area or areal density, depending on arm site.

Figure 3: The Relationship Between 3-year BLI and IBS

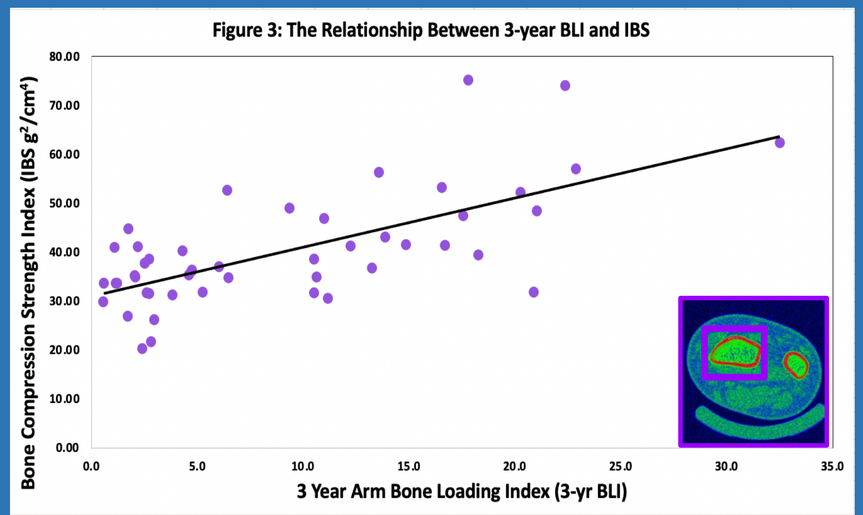
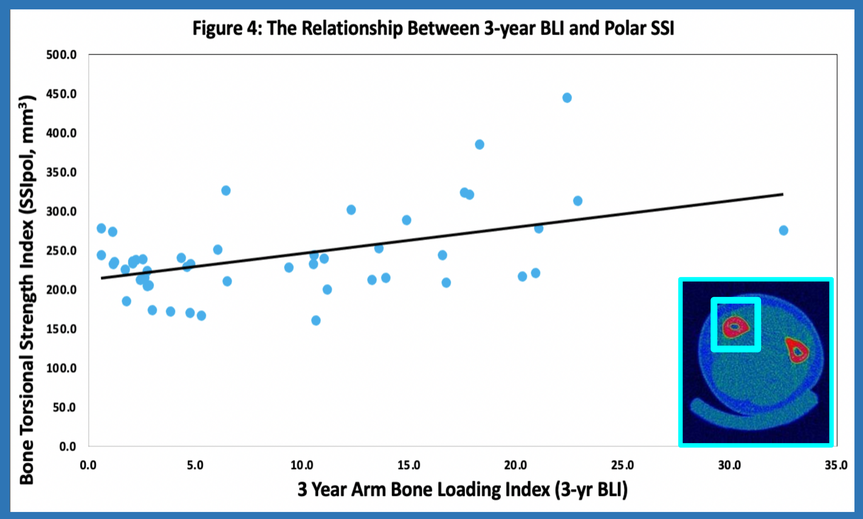


Figure 4: The Relationship Between 3-year BLI and Polar SSI



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METHODS (continued)

- We analyzed resultant data from the parent study at Upstate Medical University:
  - Predictors: maturity & body size at scan time; *diet & loading* to build the bone
    - Gynecological Age (years post-menarche)[5]
    - Height (cm)
    - Whole body non-bone lean mass (kg)
    - 3 year Arm Bone Loading Index (3yrBLI, 3 years prior to scan)[5]
    - ***Diet: Mean Intakes*** from 6 monthly data for 3-6 years Harvard Youth Adolescent Questionnaire[4] protein, total fat, calcium, magnesium, potassium, zinc, and lactose
  - Dependent variables (post-menarcheal bone properties)
    - pQCT 3D bone strength: compression (IBS, g^2/cm^4) & torsion (SSIpol, mm^3)
    - DXA 2D Bone Area (cm^2) Areal Bone Mineral Density (BMD) (g/cm^2)
- Analysis through Excel:
  - Diet assessments frequency table [Table 1]
- Analysis through SPSS v27 including:
  - Descriptive statistics (frequencies; mean, standard deviation, min., max.)
  - Multiple linear regression to predict pQCT IBS & SSI entering predictors: gynecological age, height, whole body fat-free mass, 3yrBLI
  - Multiple linear backward stepwise regression to predict DXA outcomes: gynecological age, height, whole body fat-free mass, 3yrBLI, nutrients [Table3]

RESULTS

Table 1: Diet Assessments Based on Seasons

Timing:	Participant#	-3	-3	-2	-2	-1	-1	SCAN	0.5	1	1.5	2	2.5	Total Assessments
Pre-Scan	1													2
Scan	2													4
Post-Scan	3													5
1 Winter	4													5
2 Spring	5													5
3 Summer	6													6
4 Fall	7													6
No Data	8													7
	9													7
	10													7
	11													8
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	48													12

Table 2: Descriptive Statistics

Variable	Mean	SD	Min	Max
Chronological Age (years)	14.6	1.2	11.9	17.2
Age at Menarche (years)	12.7	1.2	9.5	15.3
Gynecological Age (years)	1.7	0.4	0.9	2.6
Height (cm)	161.3	6.7	144.2	174.5
Weight (kg)	58.0	9.3	144.2	174.5
Body Mass Index (kg/m^2)	22.2	2.8	17.6	30.5
Whole Body Non-Bone Lean Mass (kg)	41.0	5.3	30.9	55.2
Body Fat (%)	25.3	4.9	17.9	35.9
3 Year Bone Loading Index	9.1	7.7	0.6	32.5
Mean Physical Activity (hours/week)	9.2	4.7	1.3	22.9

Table 3: Backward Stepwise Model Statistics for Non-dominant Arm DXA (n=48)

Radius DXA Output	Adj. Model R^2	β [95% CI] SPCC						
		Gyn Age (yrs)	Whole Body Lean Mass (kg)	3 Year Arm totBLI (hrs)	Protein Mean (gm)	Total Fat Mean (gm)	Calcium Mean (mg)	Lactose Mean (gm)
Ultra-Distal Area (cm^2)	0.583[c]		**+0.035** [+0.021,+0.050] **+0.616[c]**	**+0.011** [+0.002,+0.019] **+0.860[a]**	**-0.004** [-0.008,-0.001] **+0.948[a]**			
Ultra-Distal BMC (g)	0.691[c]	+0.088 [-0.025,+0.201] +0.889[123]	**+0.029** [+0.020,+0.039] **+0.899[c]**	**+0.023** [+0.017,+0.029] **+0.946[c]**	-0.003 [-0.007,+0.001] +0.431[126]	+0.003 [+0.000,+0.007] +0.446[052]		
Ultra-Distal BMD (g/cm^2)	0.661[c]	**+0.027** [+0.003,+0.051] **+0.913[a]**	**+0.005** [+0.002,+0.007] **+0.585[c]**	**+0.005** [+0.004,+0.006] **+0.859[c]**		**+0.001** [+0.000,+0.001] **+0.931[a]**		
⅓ Radius Area (cm^2)	0.548[c]		**+0.034** [+0.023,+0.045] **+0.610[c]**	**+0.007** [+0.000,+0.013] **+0.834[a]**		+0.003 [+0.000,+0.006] +0.590[093]	**+0.000** [+0.000,+0.000] **+0.565[a]**	
⅓ Radius BMC (g)	0.440[c]		**+0.024** [+0.013,+0.035] **+0.969[c]**	**+0.015** [+0.008,+0.023] **+0.913[c]**		+0.003 [-0.001,+0.006] +0.590[137]	+0.000 [+0.000,+0.000] +0.564[147]	
⅓ Radius BMD (g/cm^2)	0.211[b]	+0.030 [-0.003,+0.064] +0.990[077]		**+0.004** [+0.002,+0.006] **+0.919[c]**				+0.001 [+0.000,+0.003] +0.928[147]

Number in bold represents that specific predictor show statistics significant.
All models included height as independent variables (not shown).
For Adjusted Model R^2 and t significance of β: [a]p<0.05; [b]p≤0.01; [c]p≤0.001.
Semi-partial correlation coefficient (SPCC).
If p≥0.05, p is noted as parenthetic superscript, which meant it contributes to the significance of the other predictors for that specific region of interest.
Magnesium Mean (mg), Potassium Mean (mg), and Zinc Mean (mg) were removed from the model (p>0.15).